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The Effects of Crop Insurance Subsidies and Sodsaver on Land Use Change

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There have long been concerns that federal crop insurance subsidies may significantly impact land use decisions. It is well known that classical insurance market information asymmetry problems can lead to a social excess of risky land entering crop production. We provide a conceptual model to show that the problem will arise absent any information failures. This is because the subsidy is (*a*) proportional to acres planted, and (*b*) greatest for the most production risky land. Using field-level yield data, we follow this observation through to establish the implications of subsidies for the extent of crop production, with particular emphasis on the US Prairie Pothole Region, where cropland growth is likely to have marked adverse environmental impacts. Simulation results show that up to 3% of land under federal crop insurance would have not been converted from grassland if there had been no crop insurance subsidies. Sodsaver, a provision that eliminates crop insurance and Supplemental Revenue Assistance payments in the first five years of crop production on new breakings, will reduce grassland conversion by 4.9% or less.

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1. Introduction

The US government, via subsidies and direct payment programs, contributes to the farm sector income and incentivizes land use behavior. Some of these programs are designed for conservation and environmental protection (e.g., Conservation Reserve Program) but the majority of programs are not. Among these programs, the subsidized crop insurance program has attracted much attention because of its financial magnitude and potential land use effects. For example, in 2011, aggregate crop insurance premiums amounted to $11.8 billion and the federal government paid $7.4 billion in the form of premium subsidies (U.S. GAO 2012).[1] There have long been concerns that crop insurance and the large scale subsidies would have significant impacts on land use decisions, which is of important environmental interests because land use changes directly affect wildlife habitats, biodiversity, and water and air quality.

There are definite patterns in net crop insurance payments (Glauber 2004). Typical insurance programs will pay out considerably less than $1 for each dollar paid in premium in order to cover expenses. Over the period 2000–2007, crop growers in Montana, North Dakota, and South Dakota received $2 or more in indemnity payouts per $1 premium paid by the grower (Babcock 2008). The Central Corn Belt states (i.e., Indiana, Illinois and Iowa) are less drought-prone and have soils that are more fertile. Yet these states all had indemnity payouts of between $0.7 and $0.9 per $1 premium paid by the grower (Babcock 2008). Crop insurance rate setting is very involved, where we refer the reader to Coble et al. (2010). However,

[1] For growers who participate in the crop insurance program, the premium subsidy rate depends on the coverage level selected by the growers. As the coverage level increases from 50% to 85%, the corresponding premium subsidy rate decreases from 67% to 38%. For more information about subsidy rate we refer readers to Shields (2010).

intuition would suggest that subsidizing production activities on risky land will encourage more production on such land, and may provide a partial explanation for the geographic pattern of actuarial outcomes outlined above.[2]

Many studies have examined the impacts of government payments on land use decisions, and a few are specifically focused on federal crop insurance programs, such as Young, Vandeveer, and Schnepf 2001; Goodwin, Vandeveer, and Deal 2004; Lubowski et al. 2006; U.S. GAO 2007a; Claassen, Cooper, and Carriazo 2011 (CCC 2011 hereafter); Claassen et al. 2011. Goodwin, Vandeveer, and Deal (2004) represent the consensus that while crop insurance subsidies do incentivize cropping, the effect is not large. Other evidence is not so sanguine—Chen and Miranda (2007) conclude that crop insurance programs induce cotton crop abandonments in the Central and Southern Plains regions.

To address concerns that crop insurance may cause grassland conversion, the Food, Conservation, and Energy Act of 2008 (hereafter the 2008 Farm Act) incorporated a Sodsaver provision to limit incentives that subsidies provide farmers to bring new, and often environmentally sensitive, land into production. Sodsaver applies to the Prairie Pothole Region (PPR) states only (Iowa, Minnesota, South Dakota, North Dakota, and Montana), and only if the governor of the state requests an implementation. Specifically, if implemented, the provision would render agricultural production on land that has been converted from native grassland to cropland ineligible for crop insurance during the first five years of production. Since Supplemental Revenue Assistance Payments (SURE) program, a disaster assistance

[2] To the extent that it has been studied, economic theory supports this intuition. LaFrance, Shimshack, and Wu (2001) show that when land owners pay the same premium for a given coverage level regardless of their land's production risk, then subsidized crop insurance will bring high risk land into production because of adverse selection. However, as to be introduced, our theoretical model in this current study shows that subsidized crop insurance may bring high risk land into production while leaving low risk land uncropped even if adverse selection is absent (i.e., each land owner pays an actuarially fair premium based on her own production risk).

program introduced in the 2008 Farm Act, requires crop insurance enrollment, the Sodsaver provision implies that new breakings are not eligible for the SURE program during the first five years of production. As of May 2012, no governor of a PPR state has requested implementation of Sodsaver. The most comprehensive study to date of Sodsaver's likely effects on grassland conversion is CCC (2011). It concludes that Sodsaver would reduce grassland loss by up to 9% in seven selected counties in North and South Dakota.

We discern large gaps in the literature about the land use effects of crop insurance. The focus has been largely at the county-level of analysis. It has not focused on the region most likely to be impacted (i.e., land at the cropping fringe in the arid Western Great Plains). The measurement of extent of insurance subsidy has been very casual. Existing work has not been able to distinguish between conversion from uncultivated rangeland to cropland or between CRP and cropland. The policy context has changed markedly since the more analytic earlier studies, culminating in Goodwin, Vandeveer, and Deal (2004), where the authors considered data over the period 1985–1993. Biofuels policies, as well as increasing global demand for food and feed, have led to a dramatic increase in corn, soybean, and wheat prices and an expansion of land under crops during the period 2006–2010. Additional insurance subsidies were provided under the Agriculture Risk Protection Act of 2000, while the 2008 farm bill introduced further risk protection through the SURE program.

By utilizing field-level yield data up to 2006 and price data over 2005–2008 in this article, we examine how crop insurance subsidies and the Sodsaver provision affect land conversion decisions, with a focus on 17 counties in the Central and North Central South Dakota areas. This area is of particular interest because (*a*) it is one of the primary duck nesting areas in North America (U.S. GAO 2007b), and (*b*) grassland conversion has marked adverse environmental impacts in this area (Stephens et al. 2008). Regarding the impacts of crop insurance subsidies and Sodsaver on land conversion, two important policy-relevant questions arise. To what extent do crop insurance subsidies and Sodsaver affect land conversion; and, are the impacts similar across locations or are some locations particularly susceptible?

To address such questions, we first need to understand a typical farmer's optimal decision problem in the presence of crop insurance, so we develop a decision model of land use. The problem here is one of comparing returns from different land uses: crop production versus non-crop production. Returns include payments from government interventions, where simulations are run over a variety of government program and market price scenarios. Second, we estimate measures of crop insurance and related subsidies under the Revenue Protection (RP) policy. We control for yield trends so as to correctly estimate the extent of risk within a given year (Just and Weninger 1999). The approach taken is similar to that in Claassen and Just (2011), who utilized US Department of Agriculture (USDA) Risk Management Agency (RMA) data at the field level. Third, we calibrate the decision model and simulate the land use effects of crop insurance subsidies and Sodsaver. Since crop yield data on grassland are not available, our simulations are focused on cropland that has been covered by the federal crop insurance program. This renders the simulation results, strictly speaking, unable to directly answer questions such as "were crop insurance subsidies to be eliminated, then how much grassland would be saved?" Instead, the simulation results answer a similar question, but from an *ex post* perspective, which can be stated as "had crop insurance subsidies been absent, then how much grassland would not have been converted?"

The only two works we are aware of that have taken a high-resolution look at the effects of farm risk management programs on land use decisions in North and South Dakota are Claassen et al. (2011) and CCC (2011). By fitting a mixed logic model, Claassen et al. (2011) estimated the land use consequences of crop insurance and disaster payments in 77 selected counties of the Dakotas. Focusing on seven selected counties in the Dakotas, CCC (2011) constructed representative farms in the PPR and then simulated Sodsaver's land use effects. However, the studies in both Claassen et al. (2011) and CCC (2011) were (a) based on county-level yield data that may not capture farm-level yield risk, and (b) did not include harvest price to determine revenue guarantee, while in reality the most popular revenue insurance policy, RP, involves harvest price when determining revenue guarantee.[3] As we have mentioned above, in this article we utilize the field-level yield data to estimate production risk under RP policy. Moreover, we study the land use effects of crop insurance subsidies that is absent in CCC (2011).

Our conceptual model shows that crop insurance subsidies, even without information asymmetry problems, can drive a social excess of risky land entering crop production. This is because the subsidy is (*a*) proportional to acres planted, and (*b*) greatest for the most production-risky land. Using field-level yield data, we follow this observation through to establish the implications of subsidies and Sodsaver for the extent of crop production. Simulation results show that up to 3% of land under federal crop insurance would have not been converted from grassland if there had been no crop insurance subsidies. Sodsaver, if applied, would reduce grassland conversion by 4.9% or less.

The article proceeds as follows. In the second section we develop the theoretical model. Section 3 studies utility effects of revenue insurance, SURE payments, and Sodsaver. Section 4 discusses the simulation methods and data. Section 5 presents simulation results and Section 6 presents conclusions.

2. Yield Risk and Distorted Planting Decisions

We consider the matter of how the extent of yield risk can affect planting decisions in the presence of a crop insurance subsidy. The analysis pertains to many land units, each with a

[3] For example, in 2011 South Dakota had 79% of insured acres covered by RP (RMA 2011b). When determining revenue guarantee, RP utilizes the higher of the projected price and the harvest price. If the harvest price is excluded when determining the revenue guarantee then the revenue guarantee, and hence the land use effect of crop insurance, may be biased downward from their true values.

single owner. The land units are homogeneous in that all acres in a unit are the same. However, there is heterogeneity across units. To explore the effect of yield variability on planting choice, we assume that planting choice is discrete in that planting occurs in either all or none of the acres in a land unit. Let $U(\cdot)$ denote land owner's utility function of income, which is increasing and concave (i.e., $U'(\cdot) > 0 > U''(\cdot)$). We assume that the yield of one unit is

$$y = \mu + \delta\epsilon, \tag{1}$$

where $\mu > 0$ is mean yield, $\delta \in [0,1]$ is a risk parameter, and ϵ is a random variable with support $[-\mu, \mu]$, mean 0, and cumulative distribution function $G(\epsilon)$. We assume that $G(\epsilon)$ is continuous and has probability density function $g(\epsilon)$. Our interest is in yield variability only, so μ is held to be a constant while δ is heterogeneous across units with cumulative distribution function $F(\delta)$.

The alternative to cropping is to leave the land in some non-crop activities, such as pastoral farming, hunting preserve or in a conservation program. The non-stochastic return from non-crop activities is r per unit so that utility is $U^{nc} = U(r)$ whenever the land is not planted. In short, three choices exist for the owner of a land unit with risk level δ. The choices are as follows:

A. Do not crop (label as *nc*) and receive a certain utility level $U^{nc} = U(r)$;

B. Grow a crop but do not insure (label as *gni*) and face a yet-to-be-computed expected utility level $U^{gni}(\delta)$.

C. Grow a crop and do insure (label as *gi*), where the premium is subsidized at rate $s \in [0,1]$, and the yet-to-be-computed expected utility level is $U^{gi}(\delta; s)$.

Thus, the overall problem is to identify

$$V(\delta; s) = \max[U^{nc}, U^{gni}(\delta), U^{gi}(\delta; s)]. \tag{2}$$

In order to understand the decision-making process embodied in Eq. (2), it is useful to make two comparisons. These are to compare choice A with B, and to compare choice A with C.[4]

2.1 Comparing choices A and B

To establish expected utility when the land is planted we need to build up the payoffs. With output price $p > 0$ and total cost $c > 0$, under choice B (i.e., grow but do not insure) the profit is $\pi^{gni} = p(\mu + \delta\epsilon) - c.$ Therefore, we have

(3) $$U^{gni}(\delta) = \int_{-\mu}^{\mu} U(\pi^{gni}) dG(\epsilon).$$

It is readily checked that $U_{\delta}^{gni}(\delta) < 0$, and $U_{\delta\delta}^{gni}(\delta) < 0$, given $U'(\cdot) > 0 > U''(\cdot)$. This means that growers' utility under choice B is decreasing in yield risk, and decreasing at an increasing rate. Let the difference between expected utilities from choices B and A be

(4) $$\Delta^{gni}(\delta) \equiv U^{gni}(\delta) - U^{nc}.$$

We seek to identify and understand the levels of $\delta \in [0,1]$ such that $\Delta^{gni}(\delta) = 0$. We assume that under choice B the least-risky land generates higher utility from cropping than from non-cropping, and for the riskiest land the opposite is true. That is, $U^{gni}(0) > U^{nc} > U^{gni}(1)$. Therefore, there is a unique $\delta \in [0,1]$ that solves $\Delta^{gni}(\delta) = 0$. Let δ^{gni} denote the solution. As $U^{gni}(\delta)$ is decreasing in δ, it follows that units with $\delta \in [0, \delta^{gni}]$ will be planted, and so the fraction of land that will be planted is $F(\delta^{gni})$. Figure 1 provides a visual presentation of this result. For future reference, we formalize this very obvious inference.

Remark 1: *Absent insurance, only units with $\delta \in [0, \delta^{gni}]$ are planted. That is, planting occurs only in units with low yield risk.*

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[4] The setting we study will allow us to view choices B and C as just one choice, because risk aversion together with a subsidy will mean that choice C is preferred over B whenever the crop insurance contract is a meaningful choice. Therefore, we need not compare B with C.

2.2 Comparing choices A and C

Now we introduce crop insurance to the model. Let ϕ denote coverage level. Then insured yield is $\phi\mu$ and the indemnity payout on each unit is $p\max[\phi\mu-(\mu+\delta\epsilon),0]$. The matter is only of interest whenever a payout occurs with strictly positive probability, so crop insurance will only be taken up by unit owners having yield risk that satisfies $\phi\mu-(\mu-\delta\mu)>0$ (i.e., $\delta>1-\phi$). The expected indemnity, and so the unsubsidized actuarially fair premium absent an administration loading factor, is

$$v(\delta)=\int_{-\mu}^{\mu}p\max[\phi\mu-(\mu+\delta\epsilon),0]dG(\epsilon). \tag{5}$$

In the presence of premium subsidy rate $s\geq 0$ the grower paid premium is $(1-s)v(\delta)$ while the subsidy is $sv(\delta)$. The following remark is key to understanding incentives in what is to follow. Its proof is in Item A of Supplemental Materials (SM).

Remark 2: *Subsidy* $sv(\delta)$ *increases in yield risk, i.e.,* $\partial[sv(\delta)]/\partial\delta>0$.

Remark 2 states that the subsidy is more extensive for riskier land. Given the subsidy, all growers with $\delta>1-\phi$ will insure in light of benefits from risk management and the subsidy. For $\delta\leq 1-\phi$ there is no benefit to insuring as the payout and premium would both equal zero, so we assume that the growers with $\delta\leq 1-\phi$ do not insure.

If the landowner plants and insures then profit becomes

$$\pi^{gi}=p(\mu+\delta\epsilon)+p\max[\phi\mu-(\mu+\delta\epsilon),0]-c-(1-s)v(\delta). \tag{6}$$

Therefore, the expected utility from choosing option C (i.e., grow and insure) is

$$U^{gi}(\delta;s)=\int_{-\mu}^{\mu}U(\pi^{gi})dG(\epsilon). \tag{7}$$

By Eqs. (6) and (7) it is readily shown that $\partial U^{gi}(\delta;s)/\partial s>0$, which implies that an increase in subsidy rate, s, enhances the utility obtained from choosing choice C. That is, for a given land unit, an increase in s may switch the relationship between $U^{gi}(\delta;s)$ and $U^{nc}(\delta)$ from $U^{gi}(\delta;s) < U^{nc}(\delta)$ to $U^{gi}(\delta;s) \geq U^{nc}(\delta)$. Therefore, we can conclude:

Remark 3: *An increase in crop insurance subsidy rate* (*i.e., s*) *expands, at least weakly, the set of units cropped.*

We define the difference between expected utility of choices C and A as

$$\Delta^{gi}(\delta;s) \equiv U^{gi}(\delta;s) - U^{nc}. \quad (8)$$

Break-even risk levels, labeled as δ^{gi}, solve $\Delta^{gi}(\delta;s) = 0$. Since we cannot be sure of the sign of $\partial U^{gi}(\delta;s)/\partial\delta$ without further qualification, we cannot be sure that any solution to $\Delta^{gi}(\delta;s) = 0$ is unique. For example, when $s = 1$ and $\phi = 0$ then $\partial U^{gi}(\delta;s)/\partial\delta < 0$; but when $s = \phi = 1$ then $\partial U^{gi}(\delta;s)/\partial\delta > 0$ (see Item B of SM for the derivation). However, if there is no subsidy (i.e., $s = 0$) then we have $\partial U^{gi}(\delta;s)/\partial\delta < 0$. Item C in SM proves this. Therefore, whenever there is a solution $\delta^{gi}|_{s=0} \in [0,1]$ to $\Delta^{gi}(\delta;s)|_{s=0} = 0$ then the solution is unique. It is true that whenever $\delta^{gni} > 1 - \phi$ then $\delta^{gi}|_{s=0} > \delta^{gni}$. This is because whenever $\delta^{gni} > 1 - \phi$ then $U^{gi}(\delta;s) > U^{gni}(\delta)$. Figure 2 depicts the land use in the presence of unsubsidized crop insurance when $\delta^{gni} > 1 - \phi$. Therefore, we can conclude the following:

Proposition 1: *Relative to no crop insurance, the presence of unsubsidized crop insurance expands the set of land farmed from* $F(\delta^{gni})$ *to* $F(\delta^{gi}|_{s=0})$ *whenever* $\delta^{gni} > 1 - \phi$. *It remains the case that cropping only occurs in units with low yield risk.*

This unsurprising result should be viewed as a reference point, because the presence of an insurance subsidy may reverse the relationship between land risk type and the decision to crop.

2.3 Distorted planting decisions in the presence of crop insurance subsidy

In this subsection, we study how the presence of crop insurance subsidies may distort the decision to crop. By "distort" we mean that insurance subsidies bring units with high yield risk instead of units with low yield risk into cropping. Recall that the level of subsidy increases in yield risk (Remark 2). When subsidy rates are large enough, then high-risk units see additional benefits from subsidies, because they may surpass the loss caused by high yield risk. Therefore, high yield-risk units may enter cropping in the presence of crop insurance subsidies. We refer to behavior in which high yield-risk units enter cropping with the specific intent of obtaining subsidies as "subsidy chasing." Subsidy chasing requires expected utility increases in yield risk (i.e., $\partial U^{gi}(\delta;s)/\partial\delta > 0$). As has been shown in Item B of SM, we cannot be sure that $\partial U^{gi}(\delta;s)/\partial\delta > 0$ without further qualification. In this article we do not intend to identify all the necessary and sufficient conditions for $\partial U^{gi}(\delta;s)/\partial\delta > 0$. We just present some sufficient conditions under which $\partial U^{gi}(\delta;s)/\partial\delta > 0$ to convey the message that subsidized crop insurance may make expected utility increasing in yield risk. Specifically, we show that if crop insurance subsidy rate and coverage level are greater than certain critical values then $\partial U^{gi}(\delta;s)/\partial\delta > 0$. Item D of SM discusses these sufficient conditions.[5]

Depending on the sign of $\partial U^{gi}(\delta;s)/\partial\delta$ and the curvature of $U^{gi}(\delta)$, the shape of $V(\delta;s)$ in Eq. (2) can have many possibilities. Figures 3 and 4 depict just two possible shapes, and so leave much unstated. In Figure 3, cropping is still only in units with low yield. Specifically, units with $\delta \in [0, 1-\phi]$ are cropped but not insured, units with $\delta \in (1-\phi, \delta^{gi})$ are cropped and insured, while units with $\delta \in [\delta^{gi}, 1]$ are not cropped.

It is also possible that the subsidized crop insurance can bring units with high yield risk under cropping, but leave units with low yield risk uncropped. Figure 4 shows an example. In

[5] An example with constant absolute risk aversion utility function and a two-point yield distribution is available from the authors upon request.

Figure 4, units with $\delta \in [0, \delta^{gni}]$ are cropped but not insured, units with $\delta \in [\delta^{gi}, \delta^{gi'}]$ are cropped and insured, and units with $\delta \in \left(\delta^{gni}, \delta^{gi}\right) \cup (\delta^{gi'}, 1]$ are uncropped. Near $\delta = 1$, the premium subsidies are high but the risk incurred is still too high to support cropping.

From the perspective of policy, Figures 3 and 4 capture some widely held concerns about the land use implications of crop insurance in some parts of the United States. Bear in mind that our analysis is not about adverse selection or moral hazard market failures as a result of asymmetric information. Information asymmetry is not necessary for cropping of riskier land. While information asymmetries may indeed be part of the story, the simplest and most direct story is that a subsidy is most valuable on the riskiest land. As pointed out in Remark 2, the effective subsidy is largest for the land with highest production risk. Figure 4 shows that the subsidy can be so strong as to reverse the intuitive ordering on how land should enter production (i.e., where demand is highest for the least risky land as a factor in production). We summarize the analysis in this subsection as follows:

Proposition 2: *Without any information failures, subsidized crop insurance can bring high-risk land into cropping while leaving low-risk land uncropped. This is because the subsidy is increasing in yield risk.*

The theoretical model predicts that subsidized crop insurance expands the set of land farmed. It also shows that there exist subsidy rates and coverage levels under which the expected utility from cropping increases with yield risk. For simplicity in the theoretical analysis, we focused on yield insurance. In our empirical investigation we incorporate revenue insurance that covers risks from both yields and prices, given the fact that 60% of insured acres are covered by Revenue Protection crop insurance plan in South Dakota in 2011 (RMA 2011b). Our empirical investigation that follows will cast light on the extent to which the set of cropland expands in response to insurance subsidies. Specifically, in the empirical part of this article we study how eliminating crop insurance subsidies or implementing Sodsaver affects farmers' land use decisions.

3. Modeling Revenue Insurance, SURE Payments, and Sodsaver

In this section, we specify the payoffs from revenue insurance, SURE payments, and Sodsaver provision for the empirical investigation. Since we assume that growers are risk averse, the action "grow and do not insure" is strictly dominated by the action "grow and insure" whenever the crop insurance is actuarially fair. When crop insurance subsidies are present, then "grow and insure" is even more preferable. Therefore, in our simulation we only compare growers expected utility from the action "grow and insure" with the reservation utility (i.e., utility from non-cropping). According to data from the 2007 Census of Agriculture, corn, soybeans, and wheat account for about 72% of acres harvested in South Dakota. Therefore, in this study we only consider these three crops for "grow and insure."

We design two sets of simulations. One is to study the land use effects of eliminating crop insurance subsidies, and the other is to study the land use effects of Sodsaver. We omit SURE payments when we study crop insurance subsidies' effect on land use decisions. This is because SURE payments became available to growers after 2008, but our yield and price data (to be discussed in Section 4) are from 2008 or earlier. The second reason is that changing crop insurance subsidies will not directly affect SURE payments.[6] Therefore, SURE payments will cancel out when we compare the grower's profits between status quo and no-subsidy scenarios. We include SURE payments when studying Sodsaver's effects.

[6] Here we implicitly assume that changing crop insurance subsidies will not affect growers' choices on crop insurance policy or coverage level.

3.1 Revenue Insurance and Effects of Crop Insurance Subsidies

Growers receive an indemnity whenever realized revenue from a crop is lower than target revenue. Hence, the indemnity per acre for crop $i \in X \equiv \{\text{corn, soybean, wheat}\}$ under a RP policy can be written as

(9) $$I_i = \max\left[\phi_i y_i^{APH} \max[p_i^{proj}, p_i^{harv}] - p_i^{harv} y_i, 0\right],$$

where ϕ_i is the coverage level chosen by the grower for crop i, y_i^{APH} is the grower's actual production history (APH) yield, p_i^{proj} and p_i^{harv} are projected price and harvest price established by RMA, and y_i is the grower's realized yield for crop i. Note that under a RP policy the target revenue is determined by the higher of projected price and harvest price. We can see that I_i is a convex function of the realized yield of crop i, which means that riskier land receives higher payout. Since the federal government subsidizes crop insurance premiums, the net indemnity can be written as

(10) $$NI_i = I_i - (1-s)E(I_i),$$

where s is the subsidy rate, and $E(\cdot)$ is the expectation operator. Therefore, the farmer's profit from growing and insuring is

(11) $$\pi = DP + CCP + \sum_{i \in X} a_i (p_i^c y_i + NI_i + L_i - \tau_i),$$

where a_i is payment acres for crop $i \in X$, p_i^c is the county-level cash price for crop i, L_i is per-acre Loan Deficiency Payments (LDPs), τ_i is production cost per acre for crop i, DP is farm-level direct payments (DPs), and CCP is farm-level counter-cyclical payments (CCPs). Item E of SM discusses LDPs, DPs, and CCPs in detail. Once π is identified, then the expected utility from growing and insuring is $E(u(\pi))$, where $u(\cdot)$ is assumed to be a constant absolute risk aversion (CARA) utility function.

If crop insurance subsidies are eliminated (i.e., $s = 0$), then by Eq. (10) we know that the net indemnity becomes $NI_i|_{s=0} = I_i - E(I_i)$. By Eq. (11) we then obtain the profit from growing and insuring without any crop insurance subsidies as

(12) $$\pi|_{s=0} = DP + CCP + \sum_{i \in X} a_i (p_i^c y_i + NI_i|_{s=0} + L_i - \tau_i).$$

Therefore, the expected utility when setting $s = 0$ becomes $E(u(\pi|_{s=0}))$. It is readily checked that $E(u(\pi|_{s=0})) \leq E(u(\pi))$. Recall that the reservation utility is U^{nc}. If $E(u(\pi)) \geq U^{nc}$ $> E(u(\pi|_{s=0}))$, then eliminating crop insurance subsidies will induce the producer to switch land use from cropping to non-cropping. However, if $\min[E(u(\pi)), E(u(\pi|_{s=0}))] \geq U^{nc}$, then eliminating crop insurance subsidies will not cause this switch. For a certain area, let A denote the total acreage of land whose owner has $E(u(\pi)) \geq U^{nc} > E(u(\pi|_{s=0}))$, and let Ω denote the total land acreage in the area. Then the land use effects of crop insurance subsidies in this area can be measured as:

(13) $$100\frac{A}{\Omega}\%.$$

3.2 SURE Payments and Effects of Sodsaver

SURE was included in the 2008 Farm Act to replace previous ad hoc disaster assistance. To be eligible for SURE payments, a producer must meet the following requirements. Their production must (*a*) be covered by at least catastrophic risk protection (CAT) for all insurable crops and by Noninsured Crop Disaster Assistance Program (NAP) for non-insurable crops;[7] (*b*) be located in a disaster county or a contiguous county, or suffer at least 50% production loss;[8]

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[7] CAT indemnifies losses in excess of 50% of APH yield at 55% of the RMA established price. NAP offers financial assistance to producers of non-insurable crops when a natural disaster occurs. For details about NAP, we refer readers to FSA (2011b).

[8] The Secretary of Agriculture determines whether or not a county is a disaster county.

and (c) suffer at least 10% production loss. The SURE payment equals 60% of the difference between the SURE guarantee and SURE total farm revenue whenever the difference is positive. If the difference is negative then the SURE payment is 0. That is, for a grower, the SURE payment in year t can be written as

$$D_t = \max[0.6(G_t - R_t), 0], \tag{14}$$

where D_t, G_t and R_t are SURE payment, SURE guarantee, and SURE total farm revenue in year $t \in \{1, \ldots, T\}$, respectively. Here T is the length of time horizon over which land is farmed.

The SURE guarantee is defined as the lesser of program guarantee and expected farm revenue. Specifically,

$$G_t = \min[1.2\sum_{i\in X} a_{it}\phi_{it} p_{it}^{proj} y_{it}^{APH}, 0.9\sum_{i\in X} a_{it} p_{it}^{proj} \max(y_{it}^{APH}, y_i^{CCP})], \tag{15}$$

where 1.2 and 0.9 are statutory factors. SURE total farm revenue in year t, R_t, is the sum of 15% of DPs, CCPs, crop production revenue, crop insurance indemnity, and LDPs. That is,

$$R_t = 0.15DP_t + CCP_t + \sum_{i\in X} a_{it}(p_{it}^{NAMP} y_{it} + I_{it} + L_{it}), \tag{16}$$

where p_{it}^{NAMP} is the national average market price received for crop i in marketing year t. From Eqs. (14)–(16) we can see that the SURE payment, D_t, is a convex function of realized yield, y_{it}. This means that owners of riskier land should expect to receive higher SURE payments.

If the Sodsaver provision is implemented, then the first five years' production on new breakings will not be eligible for crop insurance and SURE payments, but will become eligible starting in the sixth year.. If the Sodsaver provision is not implemented, then production on new breakings is eligible for crop insurance and SURE payments start from the second year.[9] During the first four years' production on new breakings, the APH yields are calculated using a

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[9]The first year's production is not usually eligible for crop insurance because at least one year's APH is required to purchase crop insurance. Although a grower can petition for insurance for the first year's production, in this article we do not model this and assume that no crop insurance is available for the first year's production.

specific procedure designed by RMA. Eq. (3) in CCC (2011) presents this procedure. Starting from the fifth year, the APH yield in a year is the simple average of actual yields in the new breaking's production history. However, when the production history is longer than 10 years, then only the closest 10 years history is utilized to calculate the APH yield.

Without Sodsaver, the grower's profit in period $t \in \{1,...,T\}$ is

$$\pi_t^{NSod} = DP_t + CCP_t + D_t + \sum_{i \in X} a_{it}(p_{it}^c y_{it} + NI_{it} + L_{it} - \tau_{it}), \tag{17}$$

where $i \in X$, and $NI_{i1} = D_1 = 0$ because the first year's production is not covered by crop insurance or SURE payments. With Sodsaver, the grower's profit in period t is

$$\pi_t^{Sod} = \begin{cases} DP_t + CCP_t + \sum_{i \in X} a_{it}(p_{it}^c y_{it} + L_{it} - \tau_{it}), & \text{whenever } t \in \{1,...,5\}; \\ DP_t + CCP_t + D_t + \sum_{i \in X} a_{it}(p_{it}^c y_{it} + NI_{it} + L_{it} - \tau_{it}), & \text{whenever } t \in \{6,...,T\}. \end{cases} \tag{18}$$

Let U^{Sod} and U^{NSod} denote the grower's expected utility obtained from farming the new breaking land with and without Sodsaver, respectively. Then U^{Sod} and U^{NSod} can be written as

$$U^{Sod} = \sum_{t=1}^{T} \beta^{t-1} E[u(\pi_t^{Sod})]; \qquad U^{NSod} = \sum_{t=1}^{T} \beta^{t-1} E[u(\pi_t^{NSod})], \tag{19}$$

where $\beta \in [0,1]$ is a discount factor. By construction we know that $U^{NSod} \geq U^{Sod}$. If $U^{NSod} \geq U^{nc} > U^{Sod}$ then the implementation of Sodsaver will induce the grower to switch from breaking the grassland to not breaking the grassland. If $\min[U^{NSod}, U^{Sod}] \geq U^{w}$ then Sodsaver will not induce the grower to switch land use. For an area, let A^{Sod} denote the total acreage of native sod whose owners have $U^{NSod} \geq U^{nc} > U^{Sod}$, and let Ω^{Sod} denote the total native sod acreage in this area. Then Sodsaver's land use effect in this area can be measured as

$$100 \frac{A^{Sod}}{\Omega^{Sod}} \%. \tag{20}$$

So far, we have specified the payoffs to study the land use effects of crop insurance subsidies and of Sodsaver. In the next section, we discuss the simulation methods and data.

4. Simulation Methods and Data

In this section, we discuss the methods and data utilized to obtain the expected utility from different land uses in the simulation. We then ask how farmers' land use decisions are affected when (a) eliminating crop insurance subsidies or (b) implementing Sodsaver. We first discuss the simulation approach utilized in studying the land use effects due to eliminating subsidies. Then we discuss the simulation approach for obtaining SURE payments and estimating Sodsaver's land use effects. Finally, we discuss the data.

4.1 Simulating Crop Insurance Subsidies' Land Use Effects

The simulation is based on farm-level yield data. The key step in the simulation is to identify farm-level yield-price joint distributions. Once these distributions are identified, then we can calculate crop insurance premiums and hence premium subsidies for each farm. By calibrating the CARA utility function, we can then compare expected utilities from "grow and insure" with the reserve utility for each grower. We discuss how to identify the farm-level yield-price joint distributions immediately.

Because of its flexibility, copula approaches are becoming increasingly popular when modeling joint distributions (Yan 2007). Examples of modeling yield-price joint distributions using a copula approach include Du and Hennessy (2012) and Zhu, Ghosh, and Goodwin (2008). Sklar (1959) showed that any continuous m-dimensional joint distribution, $F(x_1, \ldots, x_m)$, can be uniquely expressed by two components. The first comprises of m marginal distributions obtained from the m-dimensional joint distribution. The second is an m-dimensional copula, which is an m-dimensional joint distribution with standard uniform marginal distributions. Mathematically, we have

(21) $$F(x_1, \ldots, x_m) = C(F_1(x_1), \ldots, F_m(x_m)),$$

where $F(\cdot)$ is the joint distribution function of random variables $X_1, \dots, X_m$; $C(\cdot)$ is the copula function; and $F_i(x_i)$ is the marginal distribution of random variable X_i, $i \in \{1, \dots, m\}$. Define $\eta_i \equiv F_i(x_i), i \in \{1, \dots, m\}$. Then the copula function in Eq. (21) can be written as

(22) $$C(\eta_1,\dots,\eta_m) = F(F_1^{-1}(\eta_1), \dots, F_m^{-1}(\eta_m)),$$

where $F_i^{-1}(\cdot)$ is the inverse marginal distribution function of random variable X_i. In our simulation, we utilize the Multivariate Gaussian Copula (MGC) because it is one of the most commonly used copulas in risk management (Zhu, Ghosh, and Goodwin 2008).[10] The MGC can be expressed as

(23) $$C(\eta_1,\dots,\eta_m;\rho) = \Phi_m(\Phi^{-1}(\eta_1), \dots, \Phi^{-1}(\eta_m);\rho),$$

where ρ is a dependence matrix that captures dependence between the marginal distributions; $\Phi_m(\cdot)$ is the m-dimensional multivariate standard normal distribution with mean zero and correlation matrix as ρ, and $\Phi^{-1}(\cdot)$ is the inverse distribution function of the standard one-dimensional normal distribution.

Based on the MGC, once we identify the marginal distributions, $F_i(x_i)$, $i \in \{1, \dots, m\}$, and the dependence matrix, ρ, then we can obtain the joint distribution, $F(\cdot)$, by Eqs. (21) and (23). A common method used to estimate the marginals and the correlation matrix is the Inference Function for Margins (IFM) method proposed by Joe (2005). The basic idea of the IFM method can be expressed in a two-step procedure. The first step fits parameters of the marginal distributions using maximum likelihood estimation (MLE). In the second step, the dependence parameters in matrix ρ are estimated using MLE by taking the marginal distributions' parameter estimated in the first step as given. We refer readers to Joe (2005) for details about the IFM method. In our simulation, instead of obtaining parametric estimations of marginals in

[10] For farm revenue modeling, Zhu, Ghosh, and Goodwin (2008) find that simulation outcomes are robust to replacing MGC with related distributions such as the Multivariate Student's *t* Copula (MTC).

the first step, we apply the kernel density estimation method to estimate the marginals. By doing this we do not need to identify specific parametric distributions for the marginals. Item F of SM presents the specific procedure for estimating kernel density functions of marginals.

Once we obtain draws of m-dimensional random variables we can calculate (a) the actuarially fair premium for revenue insurance under different coverage levels, and (b) expected utility from growing each crop with insurance. Therefore, the land-use change effects of crop insurance subsidies can be calculated as we have discussed in Section 3.1.

4.2 Simulating SURE Payments and Sodsaver's Effects

The critical step when simulating SURE payments is determining under what conditions a disaster occurs in a simulation. In our simulation, following CCC (2011), we assume that a county is declared as a disaster county whenever the county-level average yield is less than the county-level trend yield by 35% or more for at least one crop. In the simulation, we obtain the county-level average yield and determine whether or not a disaster occurs in a county in a given year using the following procedure.

Procedure 1. Step 1: In a given year, t, for each county among the 17 counties that are in the Central and North Central South Dakota area and among their 15 neighboring counties that are not in the area (Figure SM1 in SM), obtain N (N = 2,000 in this study) draws with replacement from units that have actual yield in year t. Then obtain the unit-level detrended yield in year t of these drawn units.[11] **Step 2:** Calculate county-level average yield for each county using the unit-level yield residuals from Step 1 to ascertain whether a disaster occurs under the 35% county average-loss criterion. By doing so, we can identify, among the 32 counties (17 counties in the Central and North Central South Dakota area and their 15 neighboring counties), the disaster counties and their contiguous counties.

[11] The yield detrending method is to be introduced when we discuss yield data in Section 4.3.1.

Regarding Sodsaver's land use effects, we study a T-year horizon ($T = 50$ in this study). If the Sodsaver provision is implemented then during the first five year's production the producer will not receive crop insurance indemnity or SURE payment. In order to obtain county-level yield-conditioned prices for growers' profit calculation, we also need to estimate a county-level joint yield-price distribution for each county. Again, we apply the copula method when estimating this joint yield-price distribution. The estimations of county-level yield and price marginals and the dependence matrix, ρ, are discussed in Item G of the SM. Procedure 2 below describes the key steps to simulate Sodsaver's land use effects.

Procedure 2. Step 1: Draw a year randomly from a discrete uniform distribution among $\{1990, \ldots, 2006\}$. We do so because the majority of our unit-level yield data are dated in period 1990–2006. Suppose the year drawn is t. **Step 2:** For year t, run Procedure 1 to obtain N (N = 2,000 in this study) unit-level yield residuals, and then calculate county-level average yield for each county among the 17 counties in year t. **Step 3:** Based on the county-level average yield calculated in Step 2 and on the county-level yield-price joint distribution, we obtain the county-level yield-conditioned price distribution. **Step 4:** We obtain N joint price draws from the yield-conditioned price distribution in Step 3. We then utilize these joint price draws and yield draws obtained in Step 2 to calculate a producer's net revenue and SURE payment. We restrict our calculation to the 15% of least productive units among units drawn in Step 2 for each county. A unit's productivity is measured by the weighted average of its 10 actual yield observations. We do so because the intent of Sodsaver is to protect native grassland and we believe that the 15% of least productive units are closest to currently available grassland in terms of crop productivity. **Step 5:** Repeat Steps 1–4 for T times. During the first five repetitions crop insurance indemnity and SURE payments are not available to the grower whenever Sodsaver is implemented. **Step 6:** Based on results in Step 5, calculate producer's utility from cropping under scenarios both with and without the Sodsaver provision.

In this step, units are matched across years by their productivity. For example, the least productive unit in year t and the least productive unit in year $t+1$ are viewed as the same unit, and the second-least productive units in year t and $t+1$, respectively, are viewed as the same unit, and so on. **Step 7:** Repeat Steps 1–6 for M (M = 1,000 in this study) times to obtain expected utility from cropping under scenarios both with and without the Sodsaver provision. That is, we obtain U^{Sod} and U^{NSod} in Eq. (19) for each unit among the 15% of least productive units. **Step 8:** For each county, take the summation of acreage of units that would switch from cropping to non-cropping were Sodsaver implemented and then divide this sum by the total acreage of the 15% of least productive units to obtain the land use effect of Sodsaver.

4.3 Data

In our simulation, we focus on the 17 counties in the Central and North Central South Dakota area and three major crops (corn, soybeans, and wheat) in this area. In this sub-section, we discuss county-level yields, unit-level yields, projected prices, harvest prices, harvest-time cash prices, production cost, and pasture land cash rent. Other data and parameters used in the simulation, such as DP yields, DP rates, LDP rates, absolute risk averse coefficient, etc., are described in Item H of SM.

4.3.1 Crop Yields

County-level yields and harvested acres data for corn, soybeans, and wheat from 1960– 2009 are obtained from National Agricultural Statistics Service (NASS) of US Department of Agriculture (USDA).[12] Unit-level yields for these three crops are obtained from the USDA Risk Management Agency (RMA). RMA yield data contains actual yield for each insured unit under the federal crop insurance program. An insured unit can be a single field or several fields

[12] For wheat, the time range is from 1960 to 2008.

depending on the physical characteristics of the farm and the grower's preferences. The yield history has up to 10 years yield records for each insured unit. In our simulation, a unit is selected only if it has 10 years of actual yield observations. However, the 10 years are not necessarily continuous. For example, a unit's first actual yield observation may be in 1990 but the second may be in 1995.

In our simulation, we use RMA yield data associated with crop insurance policy year 2007, which includes field-level actual yield up to 2006 for each insured unit. Then we further restrict these RMA field-level yield data to be within period 1987–2006**.** We do so to better accommodate the detrending method we apply, in which we incorporate the county-level yield trend—estimated using a nonparametric method of weighted local regression (Claassen and Just 2011)—to determine the unit-level yield trend. This nonparametric method estimates the county-level yield trend in a given year by using yield observations in neighboring years and by assigning a weight for each of these yield observations according to their distance from the given year. We select timeframe 1987–2006 for field-level yield, and 1984–2009 for county-level yield. We do this so that the county-level yield trend to be incorporated in the unit-level yield trend (i.e., 1987–2006) has neighboring years both before and after a year in 1987–2009. For estimating yield trend in a given year, having neighboring years both before *and* after this given year provides more trend information than does only having neighboring years before *or* after this given year. Item I of the SM provides an illustration of the detrending procedure.

Since our RMA yield data sets for corn, soybeans, and wheat are separate data sets and the location information within a county is not released by RMA, we cannot link these three data sets by units. That is, for example, in the RMA corn yield data set, we have corn yield observations for unit A, but we cannot identify unit A in the RMA soybean or wheat data sets. One approach to establish a link across datasets is to quantile match unit-yields. The basic idea is straightforward— we match units having high corn yield with units having high soybean yield or wheat yield, based on the assumption that high quality land tends to have high yield for corn, soybeans, and wheat. Item J of SM describes the specific matching procedure.

4.3.2 Crop Prices

The simulation utilizes three types of crop prices. They are projected prices, harvest prices, and cash prices. Projected prices and harvest prices have two uses in our simulation: (*a*) to determine crop insurance indemnity and SURE guarantee (see Eqs. (9) and (15)); and (*b*) to estimate joint yield-price distributions (see Items F and G in the SM). According to RMA (2011a), the projected prices and harvest prices for the three crops in South Dakota are determined as follows. For corn, a year's projected price (harvest price) is the average daily settlement price in February (October) for the Chicago Board of Trade (CBOT) December corn futures contract. For soybean, the projected price (harvest price) is the average daily settlement price in February (October) for the CBOT November soybean futures contract. For spring wheat, the projected price (harvest price) is the average daily settlement price in February (August) for the Minneapolis Grain Exchange (MGE) September wheat futures contract.

For corn and soybeans, we obtain CBOT futures prices between 1960 and 2011 from Barchart.com. For wheat, we obtain MGE futures prices between 1973 and 2011 from the same source. During 1973–1978, February price data for the MGE September wheat futures contract are not available. Therefore, to project wheat prices during 1973–1978 we utilize the average daily settlement price in March, instead of February, for MGE September wheat futures contract.

Cash prices are utilized in calculating growers' profit from cropping (see Eqs. (11), (12), (17), and (18)). Cash prices are obtained by adding county-level basis to harvest prices drawn from the estimated yield-price joint distribution. For a given year, county-level basis is obtained by subtracting the harvest price from the simple average of posted county prices (PCP) in the harvest month. For corn and soybeans we let October be the harvest month, while for spring wheat the harvest month is assumed to be August. The PCP data is obtained from USDA's Farm Service Agency (FSA).

4.3.3 Production Costs

Janssen and Hamda (2009) report a spring crop budget in the Central and North Central South Dakota area in 2008. Excluding crop insurance premium and land charge, their per acre production costs for corn, soybeans, and wheat are $205, $145, and $180, respectively. The production costs excluding crop insurance premium and land charge are labeled as basic production costs. We assume that each farm in the area has the same basic production cost in a given year. The crop insurance premium (to be calculated) and land charge (i.e., the opportunity cost of farming the land, which we assume to be pasture land cash rent) may differ across farms. Since we do not have production cost information in the Central and North Central South Dakota area in years earlier than 2008, we use a ratio to scale the 2008 basic production costs to obtain production costs in earlier years. The ratio is defined as production costs in this earlier year in the South Central North Dakota area divided by costs in 2008 in the same area.13 For example, we use the ratios of 2005 costs over 2008 costs from South Central North Dakota budgets to scale up or down the aforementioned amounts $205, $145, and $180, to obtain 2005 production costs in the Central and North Central South Dakota area for our simulation.

4.3.4 Pasture Land Cash Rent

Pasture land cash rent is the assumed opportunity cost of cropping in our simulation. County level pasture land cash rents in 2008 for the 17 counties are obtained from NASS. The NASS pasture land cash rent data does not differentiate between high quality and low quality pasture

[13] Production costs in the South Central North Dakota area over 2004–2012 are available online at: http://www.ag.ndsu.edu/farmmanagement/crop-budget-archive (accessed on 5/1/2012). The South Central North Dakota area is selected because it is contiguous to the Central and North Central South Dakota area.

land, but it is reasonable to assume that higher quality fields should have higher opportunity costs (here pasture land cash rent). Therefore, in our simulation we use the ratio of RMA unit average yield over county average yield to multiply the county-level cash rent when estimating unit-level cash rent. Since county-level pasture land cash rents for years earlier than 2008 are not available, we use the state-level increase in the rate of pasture land cash rent over years in South Dakota to derive the cash rents in years previous to 2008.[14] Data on annual changes in pasture land cash rents are calculated using state-level cash rent data from the USDA's Agricultural Statistics Board (2008).

5. Simulation Results

We simulate the land use consequences of crop insurance subsidies and of Sodsaver under four scenarios in which projected crop prices during planting seasons are from years 2005–2008. Table 1 shows these projected prices. We can see that when compared with 2005 prices, 2008 prices had increased by approximately 150%.

5.1 Land Use Consequences of Crop Insurance Subsidies

Table 2 presents the simulation results for crop insurance subsidies' land use consequences. Bearing in mind that the data pertain to land that is already cropped and insured, the results in Table 2 should be explained as the percentage of land covered under crop insurance that would have not been converted from grassland if there had been no crop insurance subsidies. Since the units included in our data have already been enrolled in the federal crop insurance program, ideal simulation results would be that for each unit the expected utility from cropping and insuring is greater than the reserve utility, i.e., $U^{gi} > U^{nc}$. However, our simulation results do not reach,

[14] For instance, suppose county A's pasture land cash rent in 2008 was \$40/acre and the state-level pasture land cash rent increased by 20% from 2007 to 2008. Then the derived pasture land cash rent for county A in 2007 is $40/(1+0.2) \approx \$33.3/\text{acre}$.

although they are very close to, this ideal situation. That is, for some units in our simulation $U^{gi} < U^{nc}$ holds.15 The reasons for this curiosity may be as follows. First, we have very limited information regarding land owners' heterogeneity, and hence we assume that they have the same utility function and basic production costs. Second, there may be scope economies in production, such that some units in the data might have been converted because they are near land that is profitable to crop, so the marginal costs of planting on these units are low.

The results show that if projected crop prices had been as those in 2005 or 2006, and if there had not been crop insurance subsidies, then about 2.7% of acres under crop insurance in the 17 counties would have provided more economic surplus to the owner under grassland than under cropland. If projected crop prices had been as high as those in 2008, and if there had not been subsidies however, then about 0.03% of acres in the same area covered by crop insurance would not have been converted. This is intuitive because when crop prices are very high then planting crops becomes so profitable that growers prefer planting even without insurance subsidies. Of course, it warrants emphasis that when commonly held expectations regarding long-run equilibrium price levels adjust upwards then the marginal land will be grassland and not land that is presently under cropping. For such grassland, crop insurance may be the decisive factor.

When crop prices are relatively low, then the availability of crop insurance subsidies may become a critical factor that influences growers' land use decisions. Therefore, we see that under 2005 and 2006 price scenarios the land use consequences of subsidies are large, but in 2008 the land use consequences are small. The average of crop insurance subsidies' land use effect over the four price scenarios is 1.6%. If we exclude results from 2008, then the average effect is 2.2%. Based on data between 1998 and 2007, Claassen et al. (2011) found that the

[15] In our simulation, when crop insurance is subsidized at current rates (see Table 1 in Shields (2010)), then for the 17 counties in total the percentage of units that have $U^{gi} < U^{nc}$ under price scenarios from 2005 to 2008 are 6.1%, 6.4%, 1.5%, and 0.1%, respectively.

average effect of crop insurance, including subsidies, is 1%. Although we do not directly simulate the land use effect of eliminating subsidies and crop insurance, Proposition 1 suggests that such effect will be larger than that of only eliminating subsidies. Given that expected net indemnities over 1998–2007 were stable (Figure 24 in Claassen et al. (2011)), we can conclude that land use consequences of crop insurance in our study are larger than those in Claassen et al. (2011), but still small.

The relationship between the magnitude of insurance subsidies' land use consequences and projected crop prices is not necessarily monotonically decreasing. From Table 2 we see that for 12 of 17 counties the land use consequences of subsidies reach the highest levels under the 2006 price scenario, and decrease over the 2007–2008 price scenarios. For four counties (Faulk, McPherson, Potter, and Sully), the land use consequences reach the highest levels under 2005 price scenario and then decrease as projected prices increase. Therefore, we propose that generally the magnitude of subsidies' land use consequences and projected crop prices have an inverse U-shaped relationship, which can be justified as follows. In our simulation, were crop prices very low (an extreme example would be 0), then regardless of whether there are crop insurance subsidies the land owners would prefer to keep their land uncropped (i.e., no land owners would switch their land uses due to the change in subsidies' availability). Therefore, the simulated land use effect of subsidies is zero. Similarly, were crop prices extremely high, then all land owners would prefer to put their land under cropping, even if crop insurance subsidies are eliminated; therefore, the subsidies' land use effect is also zero.

The results also show that, among the 17 counties included in our simulation, subsidies' land use consequences in counties close to the Missouri River are generally larger than those in the other counties (Figure 5). One explanation is that counties near the Missouri River have higher yield risks than do the other counties. As we have shown in Remark 3 and Proposition 2, subsidized crop insurance brings risky land into cropping, which implies that owners of risky land are more sensitive to crop insurance subsidies.

5.2 Effects of Sodsaver

As we have mentioned in Procedure 2, in the simulation for Sodsaver's effects we restrict our analysis to the 15% of least productive units among units in each county.[16] We then identify units whose growers would regret having converted were Sodsaver implemented. We then calculate the percentage of such units among the 15% of least productive units for each county (see Procedure 2).

Table 3 provides simulation results for Sodsaver's land use effects. We can see that, comparing the 2005 price scenario with the 2008 price scenario, the 5-year expected NPV of SURE payments increases from about $5/acre to $9/acre. Similarly, the 5-year NPV of net indemnity payments increases from about $34/acre to $74/acre. Under a given price scenario, the variation of 5-year NPV of SURE payments or net indemnity is large across counties. For example, under the 2008 price scenario the county average SURE payments range from $7/acre (Brule County) to $45/acre (Buffalo County and McPherson County). Counties in the western part of the studied area (e.g., Buffalo, Campbell, Hughes, and Hyde) have higher SURE payments and net indemnity per acre than do the counties in the eastern part (e.g., Beadle, Brown, and Spink).

Regarding Sodsaver's land use consequences, the same pattern as insurance subsidies' land use consequences holds. That is, (*a*) the consequences are significantly affected by projected crop prices, (*b*) the relationship between the magnitude of Sodsaver's land use consequences

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[16] This is one reason why we observe negative market profit in the simulation results for some counties, especially under 2005–2006 price scenarios (see Table 3). The second reason for the negative profit is that, as mentioned before, these 15% of least productive units might have been converted only because they are contiguous to fertile land so that these units induce a lower production cost that is not reflected in the simulation.

and projected crop prices is also inverse U-shaped, and (*c*) the consequences are larger in western counties of the studied area (Figure 6). Table SM1 contains simulated probabilities that a county becomes a disaster county or is contiguous to a disaster county in a typical year.[17] Under the 2007 price scenario, Sodsaver's land use consequences reach the highest value, 4.9%, among the four scenarios. Here the value 4.9% should be interpreted as follows: if in each year the projected crop prices had been the same as those in 2007 over 50 years, and if the Sodsaver provision had been implemented, then about 4.9% of acres among the 15% of least productive insured cropland would not have been converted from grassland to cropland. Under the 2008 (or 2005) price scenario Sodsaver's land use consequence is 1.2% (or 1.7%), which is smaller than that under the 2007 price scenario. The same reason for the relationship between the magnitude of insurance subsidies' land use consequences and projected crop prices applies here. The average of Sodsaver's land use consequences over the four price scenarios is 2.6%.

Six counties in our study are included in CCC (2011). These six counties are Beadle, Edmunds, Faulk, Hand, Hyde, and Sully. By constructing representative farms and utilizing 2008 crop prices, CCC (2011) conclude that in the six counties the sum of expected 5-year NPV of net indemnity and SURE payments, as a percentage of expected 5-year NPV of net return, ranges from 6.4% to 14%. Then the authors further calculate Sodsaver's land use effect by using land conversion elasticities surveyed from the literature. Their results show that Sodsaver's land use consequences in the six counties range from 1% to 9%, depending on the values of land conversion elasticity selected. Since they utilize the sum of expected 5-year NPV of net indemnity and SURE payments as a percentage of expected *5-year* (instead of a longer period that reflects cropland tenure) NPV of net return to measure Sodsaver's impact on

[17] From Table SM1 we can see that on average the probability that a county becomes a disaster county or is contiguous to a disaster county in a typical year is about 0.55. This value is close to the probability in reality calculated according to FSA's reports about SURE disaster incidents over 2009-2011 (available online at http://www.fsa.usda.gov/Internet/FSA_File/2011_sure_gis_ytd.pdf), which is 0.61.

farmers' expected net revenue, Sodsaver's land use consequences may be enlarged. In our simulation, we assume that once it is converted from grassland to cropland the converted land will be farmed for 50 years. Although the results from CCC (2011) and from this study are close, the results from these two studies are not directly comparable because the methodology and data are different. Table SM2 in the SM presents a comparison of the expected 5-year NPV of SURE payments and net indemnities calculated by CCC (2011) and by this study. We can see that on average the sum of SURE payments and net indemnities as a percentage of market profit in CCC (2011) is very close to that in this study (9.89 in CCC (2011) and 10.37 in this study under the 2008 price scenario). Therefore, once their results are adjusted by considering a much longer time horizon, the adjusted results would be significantly smaller than this study's results concerning Sodsaver's land use consequences. Specifically, were the 50-year horizon considered in CCC (2011) then a rough calculation would show that instead of up to 9%, Sodsaver's effect in their simulation would be only up to 2.7%.[18] In our simulation, Sodsaver's effect is up to 7.9% under the same price scenario (i.e., 2008) as in CCC (2011).

6. Conclusions

To understand how the availability of federal crop insurance subsidies influences land use decisions, we first develop a conceptual model of optimal land allocation in the presence of crop insurance subsidies. Our conceptual model shows that crop insurance subsidies can induce land with higher yield risk into crop production while land with identical mean productivity but lower yield risk is left uncropped. This is because the subsidy is (*a*) proportional to acres

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[18] The calculation here is conducted as follows. If interest rate is 0.07 (utilized in CCC (2011)), then a constant annual payment's 5-year NPV is about 29.7% of its 50-year NPV. Therefore, the 9% land use consequence should be scaled down by multiplying 29.7%, which is about 2.7%.

planted, and (*b*) greatest for the most production risky land, which usually includes newly converted grassland.

Using farm-level data, we follow the conceptual results through to establish the implications of subsidies for land use. We simulate the expected utility to be derived from putting land of a given production capability into crop production as subsidy rates change. Our simulation results show that risky land is more sensitive to the changes in crop insurance subsidy rates. Sodsaver's impacts on land use are also simulated. Our results indicate that crop prices are a significant determinant in the magnitudes of crop insurance subsidies and Sodsaver's land use effects. When crop prices are extremely high (e.g., the 2008 prices) or very low (e.g., the 2005 prices), then the land use effects of insurance subsidies and Sodsaver are small. When crop prices are moderate, however, then the land use effects are large.

The findings in this paper should be placed in context, as there are other channels through which crop insurance could conceivably affect land use choices. Our model is static, though dynamic features of the conversion decision are likely to be economically significant. For example, land conversion costs are not insignificant. Barnhart and Duffy (2012) estimate that it would cost about $200/acre to establish a pasture from cropland in Iowa. For converting Conservation Reserve Program land into cropping in North Dakota, Ransom et al. (2008) indicate a cost of about $50/acre, where costs might include the removal of heavy scrub and gopher mounds as well as chemical treatment. Converting native sod would be more expensive, and especially so if rocks need to be removed. A crop revenue safety net provides the owner with the assurance that subsequent conversion costs back to former uses are unlikely, and so would increase the likelihood of conversion.

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Table 1. Projected Prices in Planting Season of Corn, Soybean, and Wheat 2005–2008 ($/bushel)

	2005	2006	2007	2008
corn	2.32	2.59	4.06	5.40
soybean	5.53	6.18	8.09	13.36
wheat	3.35	4.22	5.23	11.11

Table 2. Percentage of Land under Federal Crop Insurance that Would Have Not Been Converted from Grassland Had There Been No Crop Insurance Subsidies (%)

County	under 2005 prices	under 2006 prices	under 2007 prices	under 2008 prices
Aurora	1.7	2.2	0.4	0.0
Beadle	0.2	0.2	0.0	0.0
Brown	0.2	0.2	0.0	0.0
Brule	2.0	2.6	0.7	0.0
Buffalo	2.6	3.5	5.1	0.0
Campbell	4.0	4.0	2.4	0.0
Edmunds	2.2	3.0	0.3	0.5
Faulk	1.5	1.1	0.1	0.0
Hand	1.6	2.1	0.5	0.0
Hughes	4.7	7.5	1.5	0.0
Hyde	3.4	8.5	1.9	0.0
Jerauld	0.9	3.2	1.1	0.0
McPherson	3.2	2.3	0.0	0.0
Potter	3.4	2.8	1.0	0.0
Spink	0.2	0.3	0.0	0.0
Sully	5.5	5.1	3.0	0.0
Walworth	2.8	2.9	0.0	0.0
average	2.36	3.04	1.06	0.03

Table 3. Sodsaver's Land Use Consequences and Expected 5-year NPV of SURE Payments, Net Indemnities, Revenue, and Profit under Crop Prices 2005–2008

	under Crop Prices in 2005					under Crop Prices in 2006				
County	Land Use Change (%)	SURE Payment ($)	Net Indemnity ($)	Market Profit ($)	Market Revenue ($)	Land Use Change (%)	SURE Payment ($)	Net Indemnity ($)	Market Profit ($)	Market Revenue ($)
Aurora	0.9	2	40	1	563	2.4	5	40	8	610
Beadle	6.8	2	25	111	673	3.5	4	25	158	757
Brown	0.9	1	16	268	829	1.0	3	19	273	868
Brule	1.3	2	39	-32	530	5.5	4	37	8	619
Buffalo	0.0	12	52	-126	447	0.0	19	59	-125	504
Campbell	0.0	8	41	-236	332	0.0	13	48	-246	379
Edmunds	0.5	2	31	-28	528	2.6	4	36	-10	586
Faulk	7.1	2	23	75	622	7.0	4	25	104	694
Hand	1.1	3	30	-49	507	2.4	6	32	-10	596
Hughes	0.5	4	47	-79	468	4.3	7	55	-46	563
Hyde	0.0	8	34	-175	380	0.0	13	38	-172	446
Jerauld	1.1	3	30	-8	558	4.1	5	32	14	627
McPherson	0.0	10	63	-360	215	0.0	15	75	-381	249
Potter	1.3	6	25	-40	519	3.2	9	28	-18	602
Spink	5.2	2	22	133	686	3.7	4	23	165	756
Sully	0.0	4	33	-95	453	0.5	7	37	-56	555
Walworth	1.3	4	28	-68	484	2.0	6	30	-47	556
average	1.7	5	34	-42	517	2.5	8	38	-22	586

Note: Market profit and market revenue in this table do not include SURE payment and net indemnity. Also, as we have mentioned in Procedure 2, only the 15% of least productive units are considered in the simulation.

Table 3 (continued). Sodsaver's Land Use Consequences and Expected 5-year NPV of SURE Payments, Net Indemnities, Revenue, and Profit under Crop Prices 2005–2008

	under Crop Prices in 2007					under Crop Prices in 2008				
County	Land Use Change (%)	SURE Payment ($)	Net Indemnity ($)	Market Profit ($)	Market Revenue ($)	Land Use Change (%)	SURE Payment ($)	Net Indemnity ($)	Market Profit ($)	Market Revenue ($)
Aurora	3.5	7	49	191	867	0.0	9	62	824	1619
Beadle	0.2	7	31	473	1147	0.0	9	39	1220	2009
Brown	0.1	6	26	593	1263	0.0	9	40	1249	2027
Brule	1.6	6	42	254	936	0.0	7	50	1052	1866
Buffalo	19.8	31	86	35	740	7.9	45	127	493	1344
Campbell	3.2	19	66	-153	543	6.4	35	103	190	1034
Edmunds	4.5	6	49	163	827	0.2	11	72	716	1498
Faulk	0.2	5	32	324	976	0.0	8	44	1093	1863
Hand	2.8	8	39	204	877	0.0	12	54	916	1721
Hughes	10.3	9	70	106	770	0.0	18	119	810	1623
Hyde	6.4	18	48	-49	628	5.3	32	78	448	1278
Jerauld	4.3	8	42	229	916	0.0	11	60	856	1674
McPherson	0.0	23	114	-384	323	0.9	45	175	-200	654
Potter	5.2	11	35	189	873	0.0	20	59	886	1720
Spink	0.6	7	31	434	1092	0.0	9	44	1133	1904
Sully	14.4	8	44	106	773	0.2	15	72	863	1678
Walworth	6.6	8	37	136	801	0.0	14	55	761	1559
average	4.9	11	50	168	844	1.2	18	74	783	1592

Note: Market profit and market revenue in this table do not include SURE payment and net indemnity. Also, as we have mentioned in Procedure 2, only the 15% of least productive units are considered in the simulation.

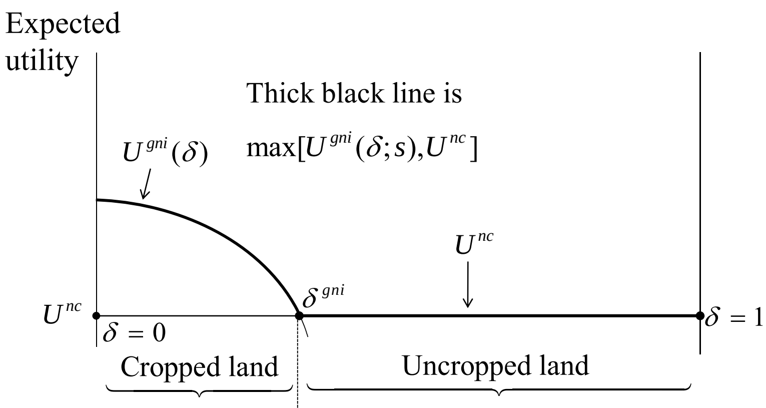

Figure 1. Maximum of uninsured expected utility and noncropping expected utility as risk changes

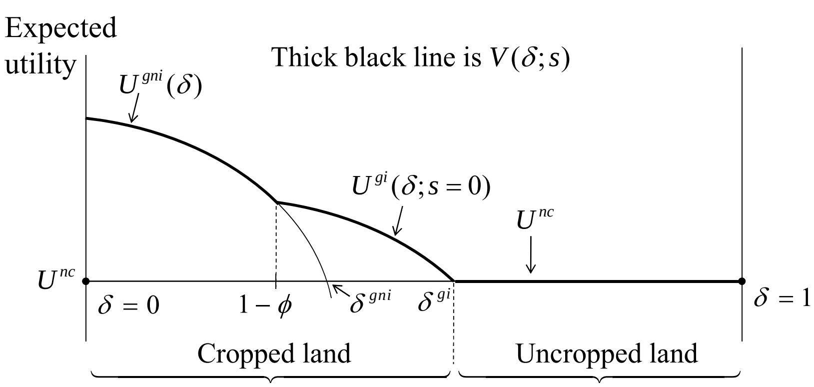

Figure 2. Land Use in the Presence of Unsubsidized Crop Insurance when $\delta^{gni} > 1-\phi$

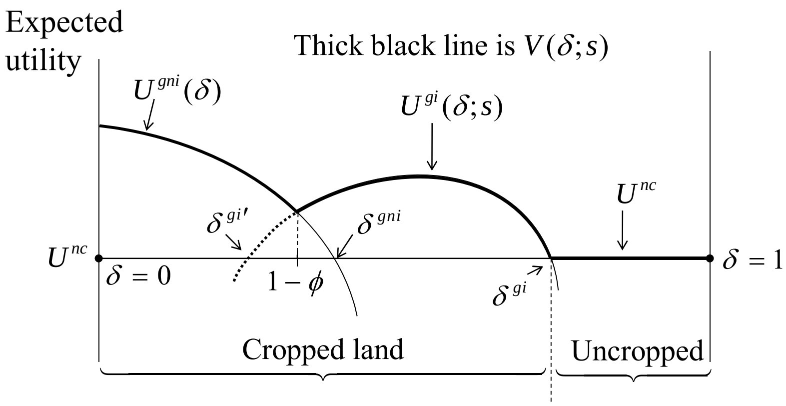

Figure 3. Subsidized crop insurance that does not distort planting decisions

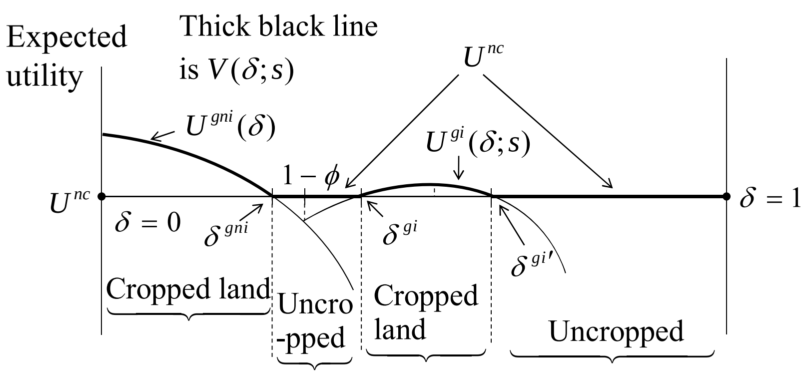

Figure 4. Subsidized crop insurance that distorts planting decisions

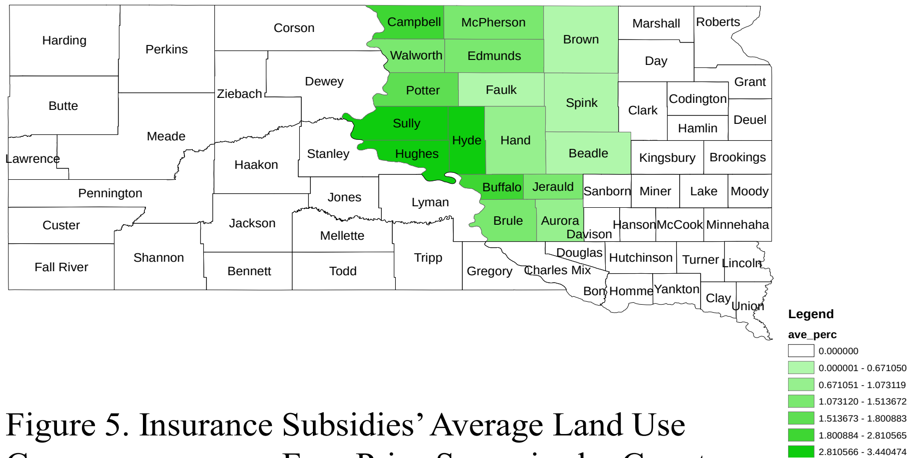

Figure 5. Insurance Subsidies' Average Land Use Consequences over Four Price Scenarios by County

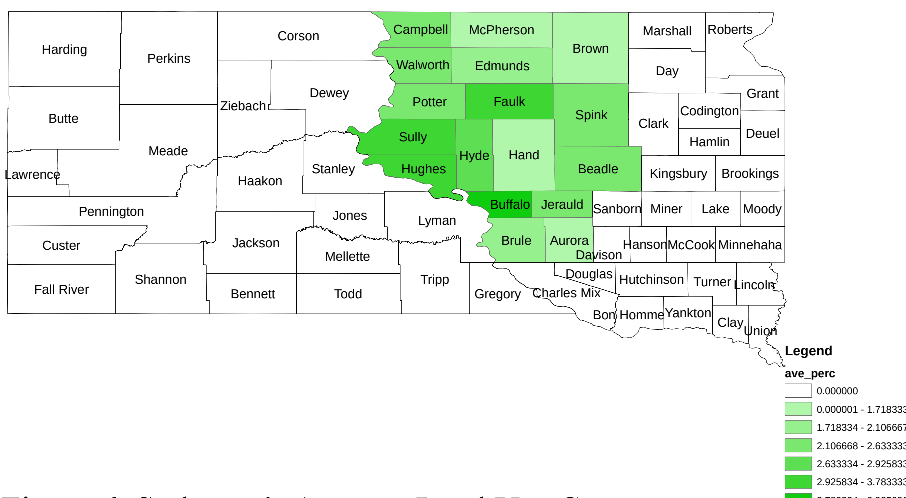

Figure 6. Sodsaver's Average Land Use Consequences over Four Price Scenarios by County

Supplemental Materials

To tidy up equations, we define $\psi \equiv \mu(\phi - 1)/\delta$ throughout the Supplemental Materials. Here ψ can be viewed as a threshold of the yield disturbance term, ϵ, because once $\epsilon < \psi$ then an indemnity payout will occur. It is readily checked that $\psi \le 0$ since $\phi \in [0,1]$, $\mu > 0$, and $\delta \in [0,1]$.

Item A

In this item we prove Remark 2 which states that subsidy, $sv(\delta)$, increases in yield risk parameter, δ. That is, $\partial[sv(\delta)]/\partial\delta > 0$.

Proof. By Eq. (5) we know that

(SM-A1)
$$\begin{aligned} v(\delta) &= \int_{-\mu}^{\mu} p \max[\phi\mu - (\mu + \delta\epsilon), 0] dG(\epsilon) \\ &= \int_{-\mu}^{\psi} p[\phi\mu - (\mu + \delta\epsilon)] dG(\epsilon) + \int_{\psi}^{\mu} 0 dG(\epsilon) \\ &= \int_{-\mu}^{\psi} p[\phi\mu - (\mu + \delta\epsilon)] dG(\epsilon). \end{aligned}$$

Therefore,

(SM-A2)
$$\begin{aligned} \frac{\partial v(\delta)}{\partial \delta} &= -\frac{\psi}{\delta} p[\phi\mu - (\mu + \delta\psi)] g(\psi) - \int_{-\mu}^{\psi} p\epsilon dG(\epsilon) \\ &= -p\int_{-\mu}^{\psi} \epsilon dG(\epsilon). \end{aligned}$$

Since $\psi \le 0$ and $dG(\epsilon) > 0$, we have

(SM-A3)
$$-p\int_{-\mu}^{\psi} \epsilon dG(\epsilon) > 0,$$

which finishes the proof. □

Item B

In this item we show that (*a*) when $s=1$ and $\phi=0$ then $\partial U^{gi}(\delta;s)/\partial\delta<0;$ and (*b*) when $s=\phi=1$ then $\partial U^{gi}(\delta;s)/\partial\delta>0.$

Proof. By Eqs. (6) and (7) we have

(SM-B1)
$$\begin{aligned}U^{gi}(\delta;s)=&\int_{-\mu}^{\psi}U\big(p\phi\mu-c-(1-s)v(\delta)\big)dG(\epsilon)\\&+\int_{\psi}^{\mu}U\big(p(\mu+\delta\epsilon)-c-(1-s)v(\delta)\big)dG(\epsilon).\end{aligned}$$

To save notation we define

(SM-B2) $\underline{\pi}\equiv p\phi\mu-c-(1-s)v(\delta)$, and $\pi(\epsilon)\equiv p(\mu+\delta\epsilon)-c-(1-s)v(\delta)$.

Therefore, we have

(SM-B3)
$$\begin{aligned}&\frac{\partial U^{gi}(\delta;s)}{\partial\delta}\\&=-\frac{\psi}{\delta}U(\underline{\pi})g(\psi)-(1-s)U'(\underline{\pi})\frac{\partial v(\delta)}{\partial\delta}G(\psi)\\&\quad+\frac{\psi}{\delta}U(\underline{\pi})g(\psi)+\int_{\psi}^{\mu}U'(\pi(\epsilon))\Big[p\epsilon-(1-s)\frac{\partial v(\delta)}{\partial\delta}\Big]dG(\epsilon)\\&=-(1-s)U'(\underline{\pi})\frac{\partial v(\delta)}{\partial\delta}G(\psi)+\int_{\psi}^{\mu}U'(\pi(\epsilon))\Big[p\epsilon-(1-s)\frac{\partial v(\delta)}{\partial\delta}\Big]dG(\epsilon).\end{aligned}$$

When $s=1$ then from Eq. (SM-B3) we have

(SM-B4)
$$\left.\frac{\partial U^{gi}(\delta;s)}{\partial\delta}\right|_{s=1}=p\int_{\psi}^{\mu}U'(\pi(\epsilon))\epsilon dG(\epsilon).$$

When coverage level is zero (i.e., $\phi=0$) then $\psi=-\mu/\delta\le-\mu.$ Therefore,

(SM-B5)

$$\begin{aligned}\left.\frac{\partial U^{gi}(\delta;s)}{\partial\delta}\right|_{s=1,\phi=0} &= p\int_{\psi}^{\mu}U'(\pi(\epsilon))\epsilon dG(\epsilon)\\ &= p\int_{-\mu}^{\mu}U'(\pi(\epsilon))\epsilon dG(\epsilon)\\ &= p[\int_{-\mu}^{0}U'(\pi(\epsilon))\epsilon dG(\epsilon)+\int_{0}^{\mu}U'(\pi(\epsilon))\epsilon dG(\epsilon)]\\ &< p[\int_{-\mu}^{0}U'(\pi(0))\epsilon dG(\epsilon)+\int_{0}^{\mu}U'(\pi(0))\epsilon dG(\epsilon)]\\ &= pU'(\pi(0))[\int_{-\mu}^{0}\epsilon dG(\epsilon)+\int_{0}^{\mu}\epsilon dG(\epsilon)]\\ &= pU'(\pi(0))\int_{-\mu}^{\mu}\epsilon dG(\epsilon)=0,\end{aligned}$$

where the second equality holds because the support of ϵ is $[-\mu,\mu]$; the last equality holds because the mean of ϵ is zero; and the inequality holds because (*a*) whenever $\epsilon<0$ then $\pi(\epsilon)<\pi(0)$, $U'(\pi(\epsilon))>U'(\pi(0))$, and $U'(\pi(\epsilon))\epsilon<U'(\pi(0))\epsilon$; and (*b*) whenever $\epsilon>0$ then $\pi(\epsilon)>\pi(0)$, $U'(\pi(\epsilon))<U'(\pi(0))$, and $U'(\pi(\epsilon))\epsilon<U'(\pi(0))\epsilon$.

When coverage level is 100% (i.e., $\phi=1$) then $\psi=0$. Therefore,

(SM-B6)
$$\left.\frac{\partial U^{gi}(\delta;s)}{\partial\delta}\right|_{s=1,\phi=1} = p\int_{0}^{\mu}U'(\pi(\epsilon))\epsilon dG(\epsilon)>0,$$

where the inequality holds because $U'(\cdot)>0$ and $dG(\epsilon)>0$. This finishes the proof. □

Item C

In this item we show that when subsidy rate $s=0$ then $\partial U^{gi}(\delta;s)/\partial\delta<0$.

Proof. We define

(SM-C1)
$$\hat{\epsilon}\equiv-\int_{-\mu}^{\psi}\epsilon dG(\epsilon).$$

By Eq. (SM-A3) we know that $\hat{\epsilon}>0\geq\psi$. Therefore, from Eq. (SM-B3) we have

(SM-C2)

$$\begin{aligned}
&\frac{\partial U^{gi}(\delta;s)}{\partial \delta}\Big|_{s=0} \\
&= -U'(\underline{\pi})\frac{\partial v(\delta)}{\partial \delta}G(\psi) + \int_{\psi}^{\mu} U'(\pi(\epsilon))[p\epsilon - \frac{\partial v(\delta)}{\partial \delta}]dG(\epsilon) \\
&= -U'(\underline{\pi})\frac{\partial v(\delta)}{\partial \delta}G(\psi) + \int_{\psi}^{\hat{\epsilon}} U'(\pi(\epsilon))[p\epsilon - \frac{\partial v(\delta)}{\partial \delta}]dG(\epsilon) \\
&\quad + \int_{\hat{\epsilon}}^{\mu} U'(\pi(\epsilon))[p\epsilon - \frac{\partial v(\delta)}{\partial \delta}]dG(\epsilon).
\end{aligned}$$

Since $U''(\cdot) < 0$ and $d\pi(\epsilon)/d\epsilon > 0,$ we have $U'(\pi(\epsilon)) > U'(\pi(\hat{\epsilon}))$ if, and only if, $\epsilon < \hat{\epsilon}.$

Moreover, by Eq. (SM-A2) it is readily checked that $p\epsilon - \partial v(\delta)/\partial \delta < 0$ if, and only if, $\epsilon < \hat{\epsilon}$.

So, we can continue Eq. (SM-C2) as

(SM-C3)

$$\begin{aligned}
&\frac{\partial U^{gi}(\delta;s)}{\partial \delta}\Big|_{s=0} \\
&= -U'(\underline{\pi})\frac{\partial v(\delta)}{\partial \delta}G(\psi) + \int_{\psi}^{\hat{\epsilon}} U'(\pi(\epsilon))[p\epsilon - \frac{\partial v(\delta)}{\partial \delta}]dG(\epsilon) \\
&\quad + \int_{\hat{\epsilon}}^{\mu} U'(\pi(\epsilon))[p\epsilon - \frac{\partial v(\delta)}{\partial \delta}]dG(\epsilon) \\
&< -U'(\underline{\pi})\frac{\partial v(\delta)}{\partial \delta}G(\psi) + \int_{\psi}^{\hat{\epsilon}} U'(\pi(\hat{\epsilon}))[p\epsilon - \frac{\partial v(\delta)}{\partial \delta}]dG(\epsilon) \\
&\quad + \int_{\hat{\epsilon}}^{\mu} U'(\pi(\hat{\epsilon}))[p\epsilon - \frac{\partial v(\delta)}{\partial \delta}]dG(\epsilon) \\
&= -U'(\underline{\pi})\frac{\partial v(\delta)}{\partial \delta}G(\psi) + U'(\pi(\hat{\epsilon}))\int_{\psi}^{\mu} [p\epsilon - \frac{\partial v(\delta)}{\partial \delta}]dG(\epsilon) \\
&= -U'(\underline{\pi})\frac{\partial v(\delta)}{\partial \delta}G(\psi) + U'(\pi(\hat{\epsilon}))\int_{\psi}^{\mu} p\epsilon dG(\epsilon) \\
&\quad - U'(\pi(\hat{\epsilon}))\int_{\psi}^{\mu} \frac{\partial v(\delta)}{\partial \delta} dG(\epsilon).
\end{aligned}$$

Because random variable ϵ's mean is 0, we have

(SM-C4) $$p\int_{-\mu}^{\mu} \epsilon dG(\epsilon) = p\int_{-\mu}^{\psi} \epsilon dG(\epsilon) + p\int_{\psi}^{\mu} \epsilon dG(\epsilon) = 0.$$

So,

(SM-C5) $$p\int_{\psi}^{\mu} \epsilon dG(\epsilon) = -p\int_{-\mu}^{\psi} \epsilon dG(\epsilon) = \frac{\partial v(\delta)}{\partial \delta}.$$

Also, from Eq. (SM-B2) we know that $\underline{\pi}$ is defined when $\epsilon < \psi$. Therefore, by $\hat{\epsilon} > \psi$ we know that $\pi(\hat{\epsilon}) > \underline{\pi}$ and hence $U'(\pi(\hat{\epsilon})) < U'(\underline{\pi})$. So, from expression (SM-C6) we have

$$\begin{aligned}
&\frac{\partial U^{gi}(\delta;s)}{\partial \delta}\Big|_{s=0} \\
&< -U'(\underline{\pi})\frac{\partial v(\delta)}{\partial \delta}G(\psi) + U'(\pi(\hat{\epsilon}))\int_{\psi}^{\mu} p\epsilon dG(\epsilon) - U'(\pi(\hat{\epsilon}))\int_{\psi}^{\mu}\frac{\partial v(\delta)}{\partial \delta}dG(\epsilon) \\
\text{(SM-C6)}\qquad &= -U'(\underline{\pi})\frac{\partial v(\delta)}{\partial \delta}G(\psi) + U'(\pi(\hat{\epsilon}))\frac{\partial v(\delta)}{\partial \delta} - U'(\pi(\hat{\epsilon}))\frac{\partial v(\delta)}{\partial \delta}(1-G(\psi)) \\
&= -U'(\underline{\pi})\frac{\partial v(\delta)}{\partial \delta}G(\psi) + U'(\pi(\hat{\epsilon}))\frac{\partial v(\delta)}{\partial \delta}G(\psi) \\
&= \frac{\partial v(\delta)}{\partial \delta}G(\psi)(U'(\pi(\hat{\epsilon})) - U'(\underline{\pi})) \\
&< 0 \ \ (\text{by } v'(\delta) > 0 \text{ and } U'(\pi(\hat{\epsilon})) < U'(\underline{\pi})).
\end{aligned}$$

This finishes the proof. □

Item D

In this item, we discuss some sufficient conditions under which $\partial U^{gi}(\delta;s)/\partial\delta > 0$. We do not intend to identify all the necessary and sufficient conditions for $\partial U^{gi}(\delta;s)/\partial\delta > 0$. We just present some sufficient conditions under which $\partial U^{gi}(\delta;s)/\partial\delta > 0$ to convey the message that subsidized crop insurance may make the expected utility increasing in yield risk.

From Eq. (SM-B4) we know that

$$\text{(SM-D1)}\qquad \frac{\partial^2 U^{gi}(\delta;s)}{\partial\delta\partial\phi}\bigg|_{s=1} = -\frac{\mu}{\delta}U'(\underline{\pi})p\psi g(\psi) > 0.$$

Moreover, Item B in the SM has shown that

$$\text{(SM-D2)}\qquad \frac{\partial U^{gi}(\delta;s)}{\partial\delta}\bigg|_{s=1,\phi=0} < 0 \text{ and } \frac{\partial U^{gi}(\delta;s)}{\partial\delta}\bigg|_{s=1,\phi=1} > 0.$$

Therefore, according to the intermediate value theorem we can conclude that there exists a unique $\phi^* \in (0,1)$, such that whenever $\phi > \phi^*$ and $s = 1$ then $\partial U^{gi}(\delta; s)/\partial\delta > 0$. Since $\partial U^{gi}(\delta; s) / \partial\delta |_{s=0} < 0$ and $\partial U^{gi}(\delta; s) / \partial\delta$ is continuous in s, we can conclude that there is a critical value of subsidy rate, $\hat{s} \in (0,1)$, such that if $s > \hat{s}$ and if $\phi > \phi^*$ then $\partial U^{gi}(\delta; s) / \partial\delta > 0$.

Item E

In this item, we discuss how to calculate Loan Deficiency Payments (LDPs), Direct Payments (DPs), and Counter-Cyclical Payments (CCPs). LDPs provide growers with payments when the county-level cash price is lower than the county loan rate. DPs pay a fixed per bushel rate to a grower based on a fixed base acre and a fixed crop yield that both are predetermined by USDA. CCPs are paid whenever the sum of (a) Direct Payment rate and (b) the higher of national marketing loan rate and the national average market price is lower than the predetermined CCP rate. For detailed explanations of these three commodity program payments, we refer readers to Vedenov and Power (2008). In what follows, we present formulas to calculate these payments.

We include a time subscript, t, for variables that may vary over time. Since our simulation for crop insurance subsidies' effect is static, the time subscript is not necessary. However, when simulating Sodsaver's effect the time subscript becomes necessary because we consider planting payoffs over cropland tenure. Let y_i^{DP} and y_i^{CCP} denote a grower's Direct Payment yield, and Counter-Cyclical Payment yield, respectively, of crop $i \in X$. Since y_i^{DP} and y_i^{CCP} are based on a farm's historical yields as determined by USDA, they do not change over time and there is no t in the subscripts. In addition, let L_{it} be per-acre LDPs, DP_t be farm-level direct payments, and CCP_t be farm-level counter-cyclical payments. Then, we have

$$\text{(SM-E1)} \qquad \begin{aligned} L_{it} &= \max[(p_{it}^{LDP} - p_{it}^{c})y_{it}, 0], \\ DP_t &= 0.85\sum_{i\in X} b_i y_i^{DP} p_i^{DP}, \\ CCP_t &= 0.85\sum_{i\in X} b_i y_i^{CCP} \max[p_i^{CCP} - p_i^{DP} - \max(p_{it}^{NAMP}, p_{it}^{LDP})], \end{aligned}$$

where p_{it}^{LDP} is the crop *i* county-level loan rate in year *t*, p_{it}^{c} is the county-level cash price for crop i in year t, p_i^{DP} is direct payment rate, p_i^{CCP} is counter-cyclical payment rate, b_i is basic acres, p_{it}^{NAMP} is the national average market price received for crop i in year t, and 0.85 is a statutory factor.

Item F

In this item we present (I) the procedure to estimate kernel density functions for marginals of unit-level yield-price joint distributions, and (*b*) the procedure to estimate the dependence matrix, ρ, for the MGC.

Let $\hat{e}_{ij}$ denote the detrended unit-level yield for crop *i*'s *j*th observation. The kernel density estimate of this unit's crop *i* marginal yield density, $f_i(x)$, can be written as

$$\text{(SM-F1)} \qquad \hat{f}_i(x) = \frac{1}{n}\sum_{j=1}^{n}\frac{1}{\lambda_i}K\left(\frac{x-\hat{e}_{ij}}{\lambda_i}\right),$$

where n is the number of yield observations of the unit; λ_i is the bandwidth for crop i, $i \in X$; and $K(\cdot)$ is the kernel function. Then crop *i*'s marginal yield distribution function can be written as

$$\text{(SM-F2)} \qquad \hat{F}_i(x) = \frac{1}{n\lambda_i}\sum_{j=1}^{n}\int_{-\infty}^{x} K\left(\frac{s-\hat{e}_{ij}}{\lambda_i}\right)ds.$$

Similarly, we can obtain crop *i*'s marginal price distribution function as

(SM-F3) $$\hat{H}_i(x) = \frac{1}{n\lambda_i}\sum_{j=1}^{n}\int_{-\infty}^{x} K\left(\frac{s-\tilde{p}_{ij}}{\lambda_i}\right)ds,$$

where $\tilde{p}_{ij}$ is define as $\tilde{p}_{ij} \equiv \log p_{ij}^{harv} - \log p_{ij}^{proj}$, and subscript *j* denotes the *j*th observation. In this study, we set $K(\cdot)$ as the Normal Kernel because it is one of the most commonly used kernel functions, and the choice of kernel function is not critical (Greene 2003, p. 455). In the simulation, the kernel density estimation is performed by using MATLAB function "ksdensity."

Regarding the estimation for dependence matrix, ρ, the procedure is as follows. The density function of the copula function in Eq. (23) can be written as

(SM-F4) $$c(\eta_1,...,\eta_m;\rho) = \frac{\partial^m C(\eta_1,...,\eta_m;\rho)}{\partial\eta_1\cdots\partial\eta_m}.$$

Then taking $\hat{F}_i(\cdot)$ and $\hat{H}_i(\cdot)$ in Eqs. (SM-F3) and (SM-F4) as given, the dependence matrix, ρ, can be estimated by

(SM-F5) $$\hat{\rho} = \arg\max_{\rho}\sum_{j=1}^{n}\log c(\hat{F}_c(\hat{e}_{cj}),\hat{F}_s(\hat{e}_{sj}),\hat{F}_w(\hat{e}_{wj}),\hat{H}_c(\tilde{p}_{cj}),\hat{H}_s(\tilde{p}_{sj}),\hat{H}_w(\tilde{p}_{wj})),$$

where the subscripts *c*, *s*, and *w* stand for corn, soybean, and wheat, respectively. In the simulation the estimation is performed by using MATLAB function "copulafit."

Item G

In this item, we discuss the estimations of county-level yield and price marginals and the dependence matrix, ρ, for the county-level yield-price joint distribution.

Regarding the county-level yield marginal distributions to be used in simulating SURE payments and Sodsaver's land use effects, we follow the same estimation method as in Du and Hennessy (2012), except that in this article we apply a locally weighted regression method to obtain county-level yield trend and residuals. The locally weighted regression method is a nonparametric method that estimates the trend in a given year by using yield observations in neighboring years and by assigning a weight for each of these yield observations according to their distance from the given year. In what follows, we present the procedure for obtaining county-level yield and price marginals and for estimating the copula.

Let $y_{i,t}^{c}$ and $\hat{y}_{i,t}^{c}$ denote the county-level yield and trend yield for crop *i* in year ***t*****.** The procedure to obtain county-level yield marginals is as follows.

Step 1: Apply the locally weighted regression method to obtain yield trend in each year, $\hat{y}_{i,t}^{c}$ (e.g., Claassen and Just 2011). Then we define the normalized residual as $\hat{\epsilon}_{it} \equiv y_{i,t}^{c} / \hat{y}_{i,t}^{c}$.

Step 2: Let $\overline{\epsilon}_i$ and $\underline{\epsilon_i}$ denote the upper bound and lower bound of $\hat{\epsilon}_{it}$, respectively. We assume that $\overline{\epsilon}_i = \mu_{\hat{\epsilon}_{i,t}} + 3\sigma_{\hat{\epsilon}_{i,t}}$ and $\underline{\epsilon_i} = 0$, where $\mu_{\hat{\epsilon}_{i,t}}$ is the sample mean of $\hat{\epsilon}_{it}$, and $\sigma_{\hat{\epsilon}_{i,t}}$ is the standard deviation of $\hat{\epsilon}_{it}$.

Step 3: The normalized yield residual $\hat{\epsilon}_{it}$ can be transformed to a standard beta random variable ξ_i by letting $\xi_i = (\hat{\epsilon}_{i,t} - \underline{\epsilon_i}) / (\overline{\epsilon}_i - \underline{\epsilon_i})$, $i \in X$. We then estimate the beta distribution parameters using MLE.

Step 4: Repeating Steps 1–3 for each county we obtain all counties' yield marginals for corn, soybean, and wheat.

When estimating the county-level crop price marginals, we follow Zhu, Ghosh, and Goodwin (2008) by assuming that the difference between the logarithms of harvest price and projected price is normally distributed. That is, for crop $i \in X$,

(SM-G1) $$\tilde{p}_{i,t} = \log p_{i,t}^{harv} - \log p_{i,t}^{proj}$$

has a normal distribution. The parameters for this normal distribution are estimated by using MLE. Then we obtain the marginal distribution for corn prices, soybean prices, and wheat prices, respectively.

Once we obtain the yield and price marginals, then the MGC dependence matrix, ρ, can be estimated by following Eqs. (SM-F4) and (SM-F5) in Item F of the SM.

Item H

In this item, we describe data for DP yields, DP rates, CCP yields, CCP rates, LDP rates, farm size, and the determination of the chosen absolute risk averse (ARA) coefficient.

County-level DP yields and CCP yields are obtained from Farm Service Agency (FSA) of the USDA. We use the ratio of unit-level average yield over county-level average yield to multiply the county-level DP yields and CCP yields to obtain the unit-level DP yields and CCP yields, respectively. DP rate and CCP rate are obtained from "2008 Farm Bill Side-By-Side" provided by USDA, available at http://www.ers.usda.gov/FarmBill/2008/Titles/TitleIcommodities.htm#direct (accessed on 5/8/2012).

DP rates for corn, soybeans, and wheat are \$0.28, \$0.44, and \$0.52 per bushel, respectively. CCP rates for corn, soybeans, and wheat are \$2.63, \$5.80, and \$3.92 per bushel, respectively. LDP rates are downloaded from "Archived LDP/PCP" webpage available at the FSA web site.[19] The county-level average farm sizes of the 17 counties are obtained from Census of Agriculture 2007.

Regarding the ARA coefficient, we follow the approach proposed by Babcock, Choi, and Feinerman (1993) that utilizes risk premium and probability premium to determine the

[19] http://www.fsa.usda.gov/FSA/displayPCPData?area=home&subject=prsu&topic=ldp-pcp (accessed on 5/8/2012).

appropriate range of ARA coefficients. They showed that the reasonable range of ARA coefficients is determined by the standard deviation of net returns (i.e., gamble size) and risk premium. In our simulation, we assume that a farmer's risk premium is 10%. That is, farmers are willing to pay 10% of the gamble size to eliminate the risk. We further assume that each farmer's gamble size is $65,000. Then by applying the approach in Babcock, Choi, and Feinerman (1993) we obtain the ARA coefficient as 3.1×10^{-6}.

Item I

In this item, we briefly introduce the procedure to obtain the unit-level detrended yield. Since the approach taken follows that in Claassen and Just (2011), we refer readers to that article for a more detailed discussion.

First, we need to obtain the county-level yield trend, which is estimated using the weighted local regression method described in Item G of the SM. Specifically, for a given county, let y_τ^c denote the county-level yield in year $\tau \in \{1,...,T\}$, and let 2*l* denote the length of a subset of $\{1,...,T\}$. Then the county level yield trend $\hat{y}_\tau^c$ for $\tau \in \{l+1,...,T-l\}$ can be predicted by using results from a weighted regression of $y_{\tau-l}^c, y_{\tau-l+1}^c,..., y_{\tau+l}^c$ on $\tau-l, \tau-l+1,...,\tau+l$ with a constant term, where the weights for the independent variable are defined by the tricube weighting function. The tricube weighting function can be written as

(SM-I1) $$w(u(\tilde{\tau})) = \begin{cases} (1-|\dfrac{\tilde{\tau}-\tau}{l}|^3)^3, & \text{whenever } -1 \le \dfrac{\tilde{\tau}-\tau}{l} \le 1 \\ 0, & \text{whenever } |\dfrac{\tilde{\tau}-\tau}{l}| > 1, \end{cases}$$

where $\tilde{\tau} \in \{1,...,T\}$.

Second, we construct a productivity measure for each unit by incorporating the county-level yield trend. That is, (SM-I2) $$\theta_{ijk} = \frac{\sum_{\tau=1}^{10} a_{ijkt} y_{ijkt} / \sum_{\tau=1}^{10} a_{ijkt}}{\sum_{t=1}^{10} q_{ikt} \hat{y}_{ikt}^{c} / \sum_{t=1}^{10} q_{ikt}},$$

where a_{ijkt} and y_{ijkt} are the unit acreage and yield for crop *i* of unit *j* in county *k* and in the *t*th year, $t \in \{1,...,10\}$, respectively; while q_{ikt} and $\hat{y}_{ikt}^{c}$ are acres harvested and trend yield for crop *i* of county *k* and in the *t*th year, respectively.

Third, the detrended unit-level yield for crop *i* of unit *j* in county *k* and in the *t*th year, $t \in \{1,...,10\}$, is

(SM-I3) $$\hat{e}_{ijkt} = y_{ijkt} - \theta_{ijk} \hat{y}_{ikt}^{c}.$$

Item J

In this item, we discuss the procedure for quantile matching units to obtain soybean and wheat yields for a unit in the RMA corn yield data set. The basic idea is that we match a corn productivity unit at the *z*th quantile with *z*th quantile soybean and wheat productivity units. We follow Claassen and Just (2011) to measure a unit's crop productivity. That is, the unit-specific productivity for a crop equals the ratio between the average unit-level yield and the average county yield trend (see Eq. (SM-I2)). The matching procedure can be presented as follows.

Step 1: Calculate the productivity measure θ_{ijk} in Eq. (SM-I2). Data for $a_{ijk\tau}$ and $y_{ijk\tau}$ are included in the RMA yield data sets. Data for $q_{ik\tau}$ are obtained from USDA NASS. Values of $\hat{y}_{ik\tau}^{c}$ are obtained by using a locally weighted regression method (see Item I).

Step 2: Based on the unit-level productivity measure obtained in Step 1, for each county and each crop estimate an empirical distribution of this productivity measure. The empirical distributions are estimated using kernel density estimation which is implemented by MATLAB function “ksdensity.” Let $G_k^c(\cdot)$, $G_k^s(\cdot)$, and $G_k^w(\cdot)$ denote the county *k* estimated cumulative distribution functions for corn, soybean, and wheat, respectively.

Step 3: Suppose a corn unit *j* in county *k* has productivity measure θ_{cjk}. Then this corn unit’s first-best soybean unit match is a soybean unit whose productivity measure is the closest to $G_j^{s-1}(G_j^c(\theta_{cjk}))$, where $G_j^{s-1}(\cdot)$ is the inverse function of $G_j^s(\cdot)$. This corn unit’s first-best wheat unit match is a wheat unit in county *k* whose productivity measure is the closest to $G_j^{w-1}(G_j^c(\theta_{cjk}))$. Similarly, this corn unit’s second-best soybean and wheat unit matches are units whose productivity measures are second closest to $G_j^{s-1}(G_j^c(\theta_{cjk}))$ and $G_j^{w-1}(G_j^c(\theta_{cjk}))$, respectively. For each corn unit, we identify the *n* (*n* = 15 in this study) closest matched soybean units and the *n* closest matched wheat units.

Step 4: Recall that each unit has a 10-year yield record. For a given year, say year τ, and for a corn unit we utilize the soybean yield in year τ from the first best matched soybean unit. If the closest matched soybean unit does not include a year τ yield, then we utilize the year τ yield from the second closest match, and so on. If none of the top *n* matches has a 2005 yield, then this corn unit is left unmatched for year τ. We do the same to identify wheat yield for this corn unit. In the simulation, we only keep corn units that have five or more successfully matched years, by which 61 out of 9,872 units are excluded.

Table SM1. Probability of A County Becomes A Disaster County or Is Contiguous to A Disaster County in A Typical Year[a]

County	Aurora	Beadle	Brown	Brule	Buffalo	Campbell
Probability	0.51	0.41	0.50	0.71	0.79	0.52
County	Edmunds	Faulk	Hand	Hughes	Hyde	Jerauld
Probability	0.50	0.45	0.61	0.64	0.79	0.67
County	McPherson	Potter	Spink	Sully	Walworth	17-county average
Probability	0.56	0.47	0.35	0.47	0.38	0.55

Note: [a] The values in this table are obtained as follows. When conducting Procedure 2, we count the frequency that a disaster occurs in a county within the 50 years period. Then we divide the frequency by 50 to obtain the probability values in this table.

Table SM2. Expected 5-year NPV of SURE Payments and Net Crop Insurance Indemnities (unit: $/acre) from CCC (2011) and from This Study

	CCC (2011)[a]			This Study[b]		
County	SURE Payment	Net Indemnity	Percent of Market Profit[c]	SURE Payment	Net Indemnity	Percent of Market Profit[c]
Beadle	9.43	40.08	8.06	8.68	39.05	3.91
Edmunds	11.49	35.04	7.70	10.51	71.80	11.49
Faulk	10.59	31.73	6.39	8.26	44.39	4.82
Hand	11.29	40.52	10.64	11.89	54.49	7.25
Hyde	15.49	42.67	12.54	32.04	78.16	24.58
Sully	17.41	41.02	13.99	15.38	72.25	10.15
average	12.62	38.51	9.89	14.46	60.02	10.37

Note: [a] Data from Table 4's "New Land Rules" panel in CCC (2011). [b] Data based on the projected prices in the 2008 price scenario. Recall that study in CCC (2011) is based on 2008 prices. [c] Here "Percent of Market Profit" stands for the sum of SURE payment and net indemnity as a percent of market profit.

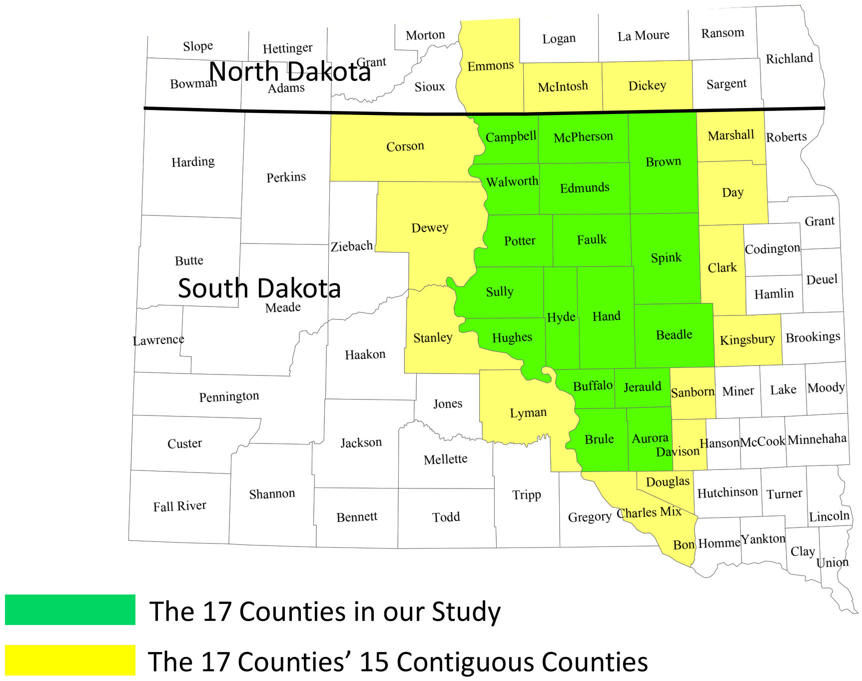

Figure SM1. The 17 Counties in the Central and North Central Area of South Dakota and Their 15 Contiguous Counties

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